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ON THE ANATOMY OF THE ANUS.

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ON THE ANATOMY OF THE ANUS.

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[N March, 1895, Dr. Robert T. Morris, of New York City, gave me some papillæ obtained from just within a human anus and asked me to determine the character of the nerves therein. The interpretation of the results obtained necessitated a study of the anal region in man and some other mammals.

Historical.—The occasional existence of papillæ in the human rectum has been long known. By many physicians they are considered pathologic and the cause of diseased conditions which are accompanied by various reflex nervous disturbances and general interference with the digestive functions. Some surgeons on general principles practise their indiscriminate removal. Numerous theories have been advanced regarding their cause and development, but, so far as I am aware, they have never been the object of scientific study. In '95, Andrews, (p. 303,) in discussing the disastrous results which frequently follow a common operation for hemorrhoids where the terminal two to three centimeters of the rectal epithelium are entirely removed (Whitehead's, or the so-called American operation for hemorrhoids), says, "The mucous membrane has a peculiar mechanism, constituting it a tactile organ, which is the seat of a very acute special sense by which a healthy person is warned of the presence and downward progress

of the fecal mass. Its nerves possess remarkable reflex powers over the sphincters so that they resist the unexpected escape of contents without constant mental attention. Just below the columns of Morgagni are about eight small papillæ. Each one has an artery and a nerve. Under its base is a little ganglionic enlargement of the nerve. They are important tactile organs connected with the special rectal sense."

Methods and Material.—The methods employed may be stated as follows:

I. Gross anatomy. A study of the anal region in the rabbit, dog, cat, monkeys, several specimens, the anthropoid apes, and man. Five apes were examined,—viz., Orang, two adult females and one young female, chimpanzee, young female, and one young male gorilla. Also five monkeys. The human material comprised ten fetuses at or near term, one child fifteen months old, and two adult human rectums.

II. Several clinical demonstrations.

III. The histologic study,—

(a) Of serial sections of papillæ fixed in the following mixture which has been recommended by Dr. P. A. Fish,—

95 per cent. alcohol	500 cc.
Water	500 cc.
Glacial acetic acid	5 cc.
Mercuric chloride	5 grms.
Picric acid	1 gm.

The tissue is to be fixed twelve to twenty-four hours, then HgCl_2 and picric alcohol washed out in 50- and 70-per-cent. alcohol. Then put into 80- and 95-per-cent. alcohol, twelve to twenty-four hours in each, and embedded in collodion. For staining sections there were used hematoxylin, fuchsin, Weigert's hematoxylin, and an original method which the writer is not quite ready to publish.

(b) Both Golgi's methods,—silver and gold. The gold method gave fairly good results, but the silver method was unsatisfactory.

(c) The gold chloride method.

(d) Fresh tissue was macerated in Haller's fluid, teased with needles, stained on the slide with fuchsin, and mounted in glyc-

erin. These preparations showed ganglion-cells and nerve fibers well.

(e) Sagittal sections of an adult human anus.

Comparative Anatomy.—The anal orifice may be described as the contracted opening of an approximately pear-shaped bag. The natural tendency of the sphincter muscles is always to contract and keep it closed without the intervention of the will. This supervision is brought about through the agency of a delicate specialized nervous mechanism,—(a) central in the lumbar enlargement of the myel; (b) peripheral, in and under the lining epithelium just within the anal orifice.

In all the mammals examined, including man, the general structural plan is the same. The transition between skin and mucosa is a narrow zone of stratified epithelium three to nine millimeters wide. Its general form may be compared to a comb or a saw with irregular teeth. Hence the term *pecten* (Latin, *pecten*, a comb) is suggested to designate it. The dentations of the *pecten* interdigitate with corresponding ones of the mucosa. (See Fig. 1.)

The mucosa cephalad of the line of junction is thrown into a series of folds. The appearance is something like that of a ruffle stitched to a scalloped band; or, perhaps, like fluted trimming. The folds cannot be entirely obliterated by dilatation of the orifice. These folds are commonly called *Morgagni's columns*, and the depressions between them *sacculi Horneri*.

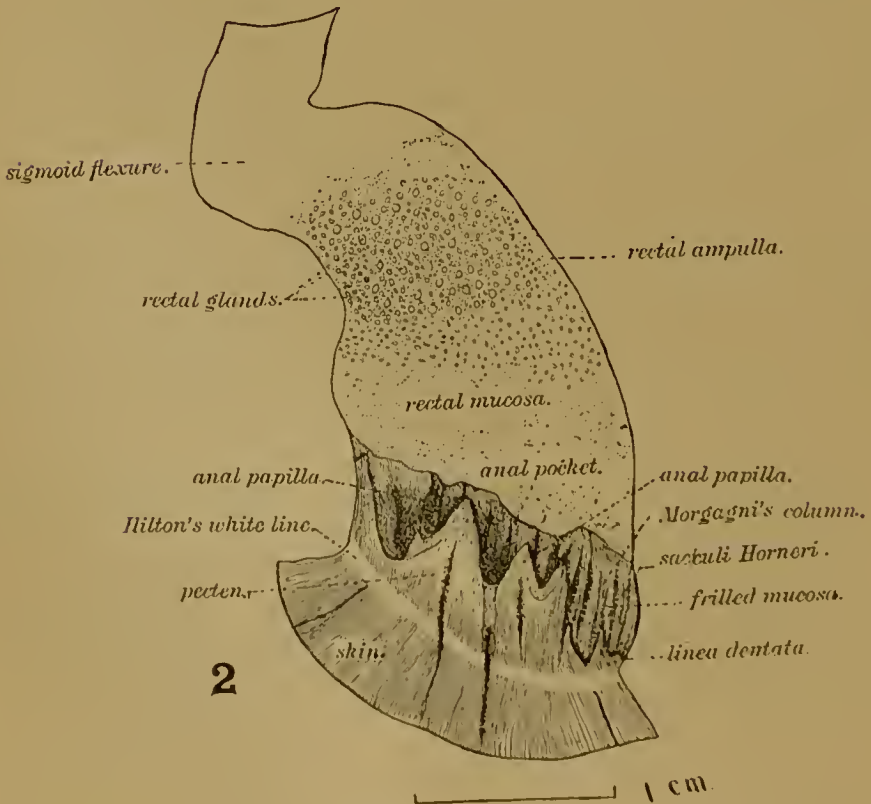
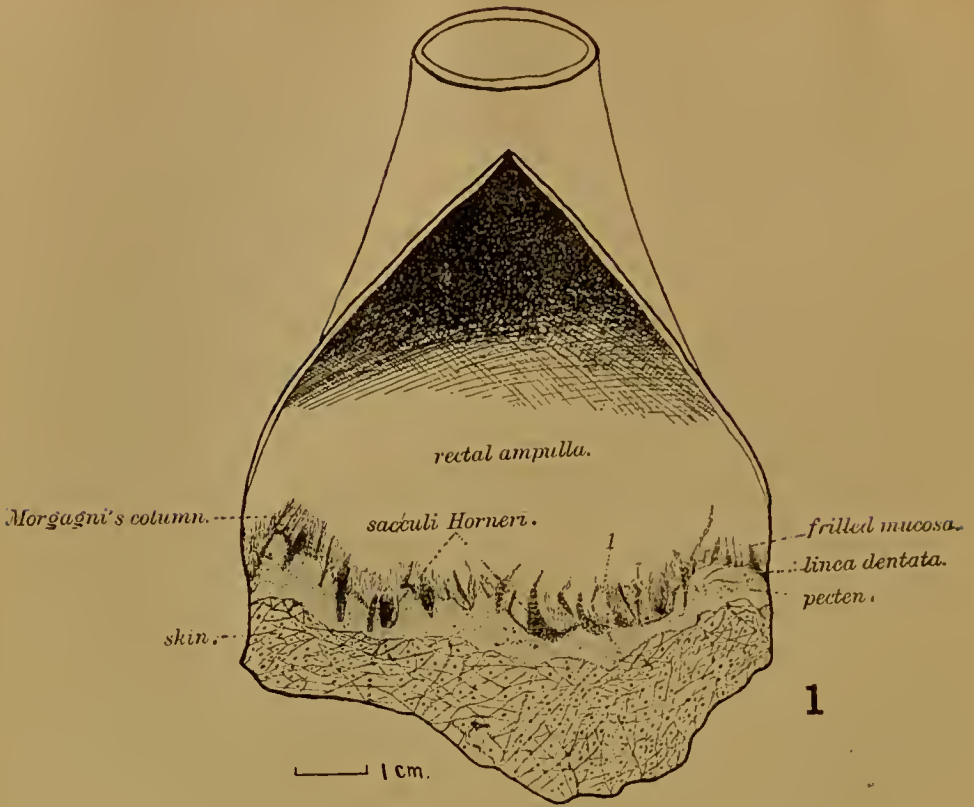
It is of interest to note that the region is most completely differentiated in man. It is well developed in the anthropoid apes. Among the lower animals it is most perfect in the cat and dog. In the latter the *sacculi Horneri* are particularly large.

Characters of the Pecten.—The *pecten* is distinguished by the following features:

(1) It is bounded caudad (ectad) by the line of junction of the ectal and ental sphincters (Hilton's white line) and cephalad by the *linea dentata*.

(2) It has a smooth, even texture and a glossy, shining appearance. The color is intermediate between those of mucosa and skin.

(3) It has few or no openings of sweat-glands.



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(4) It is moderately vascular.

(5) It is covered by a stratified epithelium which is richly supplied with nerve endings.

(6) The cephalic dentations vary in size from two to twelve millimeters wide and three to nine millimeters long; and in appearance from broad, truncated, round, or pyramidal to slender, columnar. Sometimes they present a slender neck and are expanded cephalad to a more or less bulb-like extremity. It is probable that in some cases these develop into papillæ.

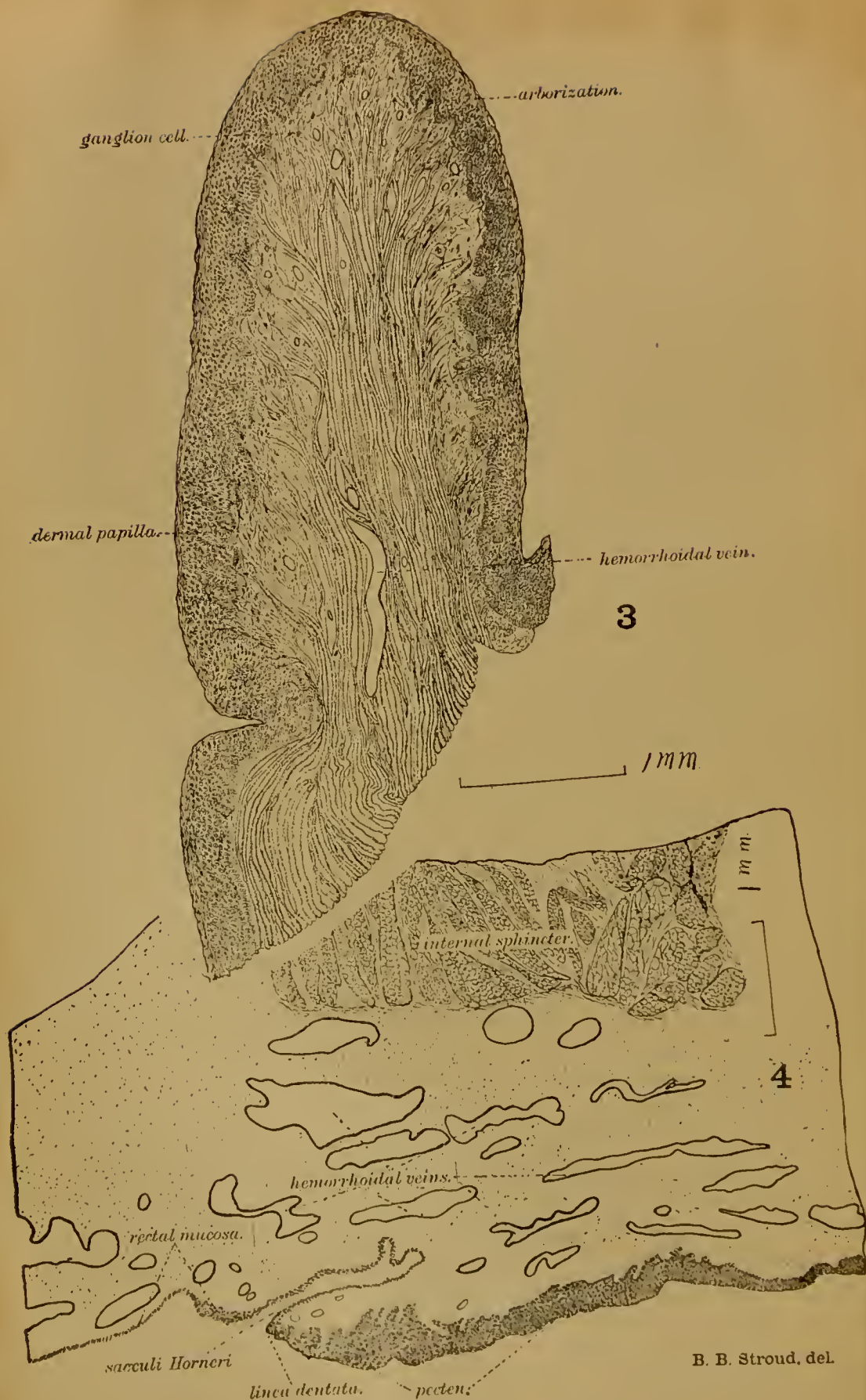
(7) The dentations are normally thrown into corrugations by the action of the sphincter muscles. Their surface is slightly more elevated than the surface of the adjoining mucosa. If I understand Andrews correctly, these are the papillæ of which he speaks.

When the orifice is closed the pecten forms the central part of the floor of the pear-shaped rectal ampulla and is directly apposed to the descending fecal mass. It is only reasonable to suppose that it should be the seat of special sense-organs whose function is to regulate the movements of the sphincter muscles.

The Frilled Mucosa.—The intervals between the folds of mucosa (Morgagni's columns) form a series of indentations or little sacculi (sacculi Horneri) placed radially in the rectal wall just cephalad of the pecten. The caudal end is usually a blind pouch (see Fig. 4, Pl. II), but in some cases there is no pouch at all. The cephalic (upper) end is freely open. The depth and extent of the individual depressions vary considerably. It has been suggested that their use is to hold a reserve of mucus for lubricating the fecal mass, but their size does not seem to warrant such a conclusion. The writer would suggest that they are simply the mechanical result of constricting the wide rectal tube to its small ectal orifice.

The epithelium covering this region is simple and composed of small oval or fusiform cells placed close together. It shows a striking contrast to the epithelium of the pecten.

Anal Papillæ.—In a small percentage of human individuals there are developed from either the tips or the faces of the pectineal dentations papillæ which project cephalo-entad into the lumen of the rectum. (See Fig. 2, Pl. I.) Fig. 1, 1 shows a small



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dentation which is almost a papilla. They vary in size from short and narrow or blunt and wide to long cylindric cones. The tip is sometimes enlarged to form a bulb. Being developed from the pecten, they are covered by a similar epithelium. The dermis appears to consist chiefly of nerve fibers, ganglion cells, and a minimum of connective tissue elements. They are to be considered as an anomaly of moderately frequent occurrence. So far as I have been able to determine they are peculiar to man. I consider them to be accessory sense-organs of a higher degree of development than the major part of the pecten and not pathologic outgrowths.

Anal Pockets.—The pectineal dentations are not usually equally developed. But in rare instances two large ones adjoin, and the depression between them is a large foliated sac or pocket. The walls of this pocket contain numerous sacculi Horneri. The outer side of the pocket is formed by a substantial fold of epithelium which unites the two dentations. In the cases examined each terminated in a well-marked papilla. (See Fig. 2.) The fold has the appearance of a valve, which, if it were sufficiently developed, might be of service in helping to retain the feces under unfavorable conditions. This, so far as I have been able to determine, is a human peculiarity and not constant. It also, like the papillæ, has been described as pathologic.

Considering these facts, a question naturally arises; is not nature in the process of evolving for man additional organs for his convenience and safeguard? A careful compilation of statistics at intervals, of say each generation, would throw light on this question.

Histology.—The histologic examination has been chiefly confined to a study of the nerve elements. The greatest difficulty was experienced in staining the nerve elements. They certainly are good examples of chromophobic nerve-cells.

The Epithelium.—The epithelium of the pecten and papillæ is thick and stratified. Three distinct zones can be distinguished.

(1) The zone of large columnar or oval cells. Most ental, having a large nucleus, a well defined nucleolus, and a narrow zone of cytoplasm.

(2) The middle zone of large plump cells embedded in a homogeneous matrix which stains less deeply than the cells. This zone forms the greatest mass of the epidermis (see Figs. 3 and 5); the cells have a large amount of cytoplasm.

(3) A thinner ectal zone of flattened tetragonal cells lying in the meshes of a homogeneous, horny stroma. These cells have a small nucleus and a large hyaline cell body.

The dermis is composed of a loose areolar tissue, which forms a supporting matrix for blood-vessels, and a perplexing net-work of amyelinic nerve fibers, fibrils, and small to giant ganglion-cells.¹ The ectal surface is thrown into a large number of elevations like the ordinary dermal papillæ. The dermis is moulded over them.

Nerve Elements.—Of these there can be distinguished,

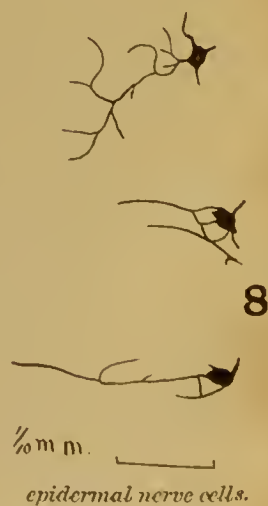
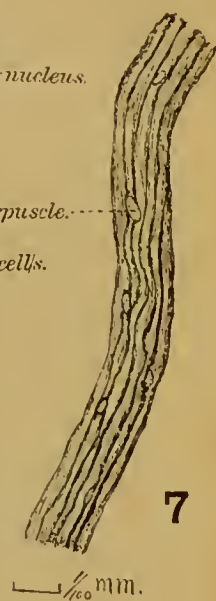
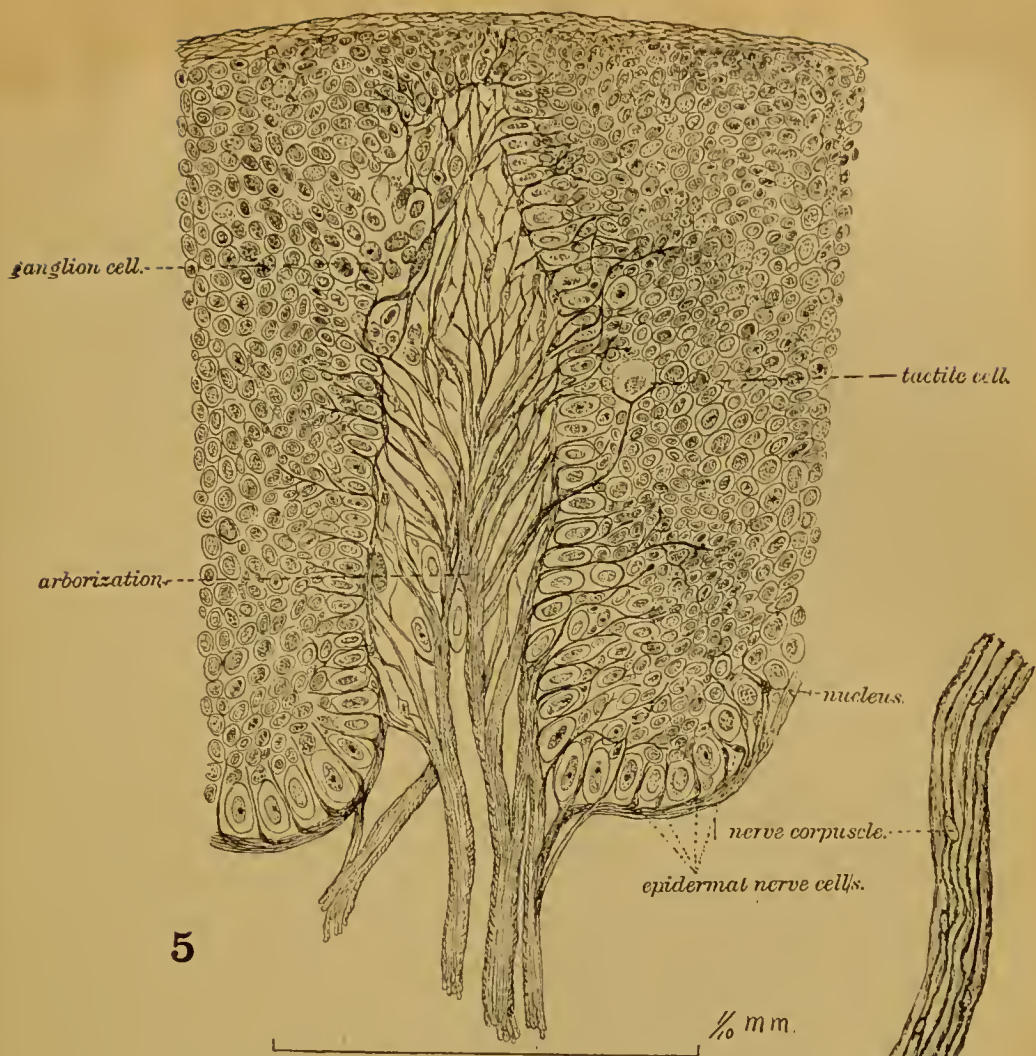
(1) The epidermal plexus, composed of small nerve-cells, from whose peripheral ends dendrites arise, anastomose with dendrites from other cells, and end in the middle epidermal zone.

(2) The dermal plexus, composed of large and small ganglion-cells which anastomose freely.

(3) Amyelinic nerve fibers, coarse trunks, five to fourteen microns in diameter. They anastomose freely. Two peculiarities in their mode of distribution were noticed. (*a*) The extension of a trunk into the base of a dermal papilla where the individual fibrils separate in a fan- or arbor-like expansion to unite with (1) the dermal ganglion-cells, (2) the epidermal nerve-cell, or (3) to penetrate directly to their termination among the cells of the middle epidermal zone. (See Fig. 5.) (*b*) Certain fibers, instead of distributing their component fibrils as in (*a*), are interposed between the dermis and epidermis,—*i.e.*, it is an interdermal fiber. (See Fig. 5, Pl. III.) It gives off short fibrils to the adjacent epidermal nerve-cells. In some cases the nerve-cells appear to be sessile upon the fiber.

The Ganglion-Cells of the Dermis.—Embedded in the ectal region of the dermis are numerous multipolar ganglion-cells. Their form varies from triangular, subtetragonal to huge elon-

¹ Much as I would prefer a mononym for *nerve-cell* or *ganglion-cell*, in the present unsettled state of opinion among neurologists, it seems best in this paper to employ the old familiar terms.



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gated subcylindric bodies. In size they vary from 21 to 109 microns long and 6 to 11 microns wide. They show best in macerated preparations, teased and mounted in glycerin. They anastomose freely, usually by means of large, coarse fibers. From the surface of the cells and the larger processes there arise, at irregular intervals, numerous fine hair-like processes whose destinations have not yet been determined. These nerve elements are probably derived from Meissner's plexus.

The Epidermal Plexus.—On account of its location the term *epidermal plexus* is suggested to designate a series of small anastomosing cells, apparently nervous, which are found chiefly wedged in between the cells of the ental layer of the epidermis; although some of them are frequently found entad and also ectad of this layer. Their form would seem to be modified by pressure from adjacent cells. It varies from oval, pyramidal to triangular and fusiform.

They vary in size from ten to 165 microns long and six to seven microns wide. Their long axis is usually ento-ectad or at right angles to the mucosa; but sometimes it is parallel with the surface. Dendrites which frequently anastomose at a short distance from the cell with similar dendrites from adjoining cells arise from the peripheral end. (See Figs. 5, 8.) They extend peripherad, often branching dichotomously and end freely among the cells of the middle epidermal zone. In some cases the end is dilated into a bulb-like enlargement. (See Fig. 5.) These cells and their branching dendrites remind one of the Purkinje cells of the cerebellum. (See Fig. 8.) The results for the ultimate terminations were not so satisfactory as might be desired.

A short neurite leaves the ental (central) end of the cell and soon joins one of the interdermal fibers. In a few cases fibers were observed which appeared to end in tactile cells.

The source of these epidermal nerve-cells is in doubt; but from anatomic and clinical observations it seems probable that their destination is the lumbar region of the myel, or, perhaps indirectly, the psychic centres in the brain.

Physiology.—The following statements are based upon the works of Foster, '95, p. 382,) Kelsey, ('90, pp. 10, 11,) and Quain, ('96, p. 117).

The Nerve-Supply of the Anus.—The rectum and anus are richly supplied with nerves from both the central and the sympathetic nervous systems.

(A) The sympathetic branches from the mesenteric and hypogastric plexuses.

(B) The central.

(a) The third and fourth sacral nerves supply visceral branches to all the pelvic organs and anastomose with the branches from the sympathetic.

(b) The caudal hemorrhoidal branch of the pudic nerve supplies the caudal end of the rectum, the ectal sphincter and the skin of the anus (pecten?). Dorsal branches from the sacral nerves also supply the skin around the anus.

(c) From the ental pudic, a dorsal branch from the ectal perineal nerve supplies the skin ventrad of the anus, the ventral branch gives off fibers to the levator ani.

Experiments have shown (Foster, '95, p. 382) that the tonic contraction of the sphincters is controlled in part by a nerve-center located in the lumbar enlargement of the myel. Yet the sphincter may be relaxed or its tonic contraction increased by local stimulation or by influence of the emotions or of the will. It further appears that a certain amount of control over the sphincter may be exercised by the sympathetic nervous system. (Gowers, '77, p. 77.)

Reflexes.—Much interest is naturally attracted to the subject of reflex nervous disturbance in general, and particular to those associated with rectal disorders. Their existence is undeniable, but the cause is not always apparent. It has been shown that the anus is the seat of a complex and highly-specialized sense-organ. This almost incomprehensible nervous apparatus furnishes the anatomic basis for all sorts of nervous reflexes; it still remains to demonstrate a sufficient exciting cause.

If we recall the fact that these delicate nerve elements, together with a multitude of small blood-vessels, are enclosed in a rather firm, supporting tissue, the dermis (see Fig. 4. Pl. II), and that a congestion of these blood-vessels will bring an unnatural pressure, proportional to the amount of congestion, upon these nerve elements, one cause for disturbance is revealed. In

the writer's judgment this may be a sufficient cause for very grave symptoms.

Acknowledgments.—To Professors B. G. Wilder and S. H. Gage, of the Anatomical Department of Cornell University, I am under deep obligations for suggestions and helpful criticism and for the use of the best anthropoid ape material. The human material has been kindly supplied by Dr. Morris and Mr. Paul M. Pilcher.

SUMMARY.

(1) The anus presents a general similarity of structure among mammals, but certain features are most highly developed in man, with approximations in the anthropoid apes and in the domestic cat and dog. The *sacculi Horneri* are especially large in the dog.

(2) The transitional epithelium between skin and rectal mucosa is a narrow zone of thick, stratified epithelium, the pecten containing nerve elements which the writer believes to be the peripheral ends of nerves concerned with a special rectal sense. This zone varies in width from about three to nine millimeters. Its caudal border is about at the junction of the ectal and ental sphincters. The cephalic (upper) border is demarcated by the linea dentata.

(3) From the dentations of the pecten in some human individuals there are developed papillæ, composed chiefly of stratified epithelium, nerve elements, and a minimum amount of connective tissue. These are believed to be important additions to the "rectal sense" apparatus, and to make the possessor physiologically superior to those individuals who have no papillæ.

(4) There are also developed in some human individuals more or less extensive anal pockets just cephalo-peripherad of the pecten. *Sacculi Horneri* are found in their walls. In the cases observed a papilla was located on each side of the pocket. Papillæ and pockets cannot be considered pathologic, since both were found in a child fifteen months old.

(5) When the sphincters are closed the pecten forms the central part of the floor of the rectal ampulla. And from Andrews's ('95, p. 303) description of Whitehead's operation for hemorrhoids, I judge that the pecten is excised in this operation.

Perhaps this fact accounts for the large percentage of incontinence of feces resulting from this operation.

(6) The caudal border of the rectal mucosa is at the linea dentata. The character of the epithelium is seen to change markedly here. (See Fig. 4, Pl. II.) And the mucosa is thrown into folds like a ruffle.

(7) Clinical observations tend to show that there are few sensory nerve elements in the rectal mucosa, since serious injuries may be inflicted, or the gravest diseases, such as ulceration or cancer, may exist without causing pain, Kelsey ('90, p. 24).

(8) Among the nerve elements present may be mentioned,—

(a) Small nerve-cells with anastomosing dendrites which form the epidermal plexus.

(b) Large ganglion-cells in the dermis.

(c) Amyelinic nerve fibers. In the sections examined all appeared to be normal.

(9) The nerve-supply of the rectum and anus is derived from both the neuron (central nervous system) and the sympathetic nervous system.

(10) The writer suggests that some rectal reflexes may be due to pressure upon the nerve elements, caused by congestion of the blood-vessels in this region. (See Fig. 4, Pl. II.)

Clinical observations appear to indicate that reflexes may also be caused by pressure upon irritated papillæ from spasm of the sphincter.

(11) Pockets may be torn by hard feces, causing a laceration of the pecten. Continued irritation and even ulceration frequently result. Some idea of the nerve terminations exposed may be obtained from Figs. 3, 4, and 5.

(12) Small hardened lumps of feces may lodge in a pocket and cause perforation of its floor, an abscess, or even a fistula.

(13) Irritated papillæ are often injected with serum.

(14) No evidence of sclerosis was found in any of the papillæ examined.

DESCRIPTION OF PLATES.

PLATE I.

Fig. 1 shows the ental aspect of an adult human anus, No. 3439, Museum of Cornell University. The specimen was hardened in alcohol, slit open, and the sides reflected. Shows the general relation of the skin, pecten, frilled mucosa, Morgagni's columns, and the sacculi Horneri. In the skin are seen the openings of numerous sweat-glands.

1 is a dentation, which, if it were large enough, would be a papilla.

The linea dentata marks the serrated cephalic (upper) border of the pecten, and also the caudal limit of the rectal mucosa. The other features need no further comment.

Fig. 2.—The rectum of a female child, fifteen months old, No. 2672, Museum of Cornell University. Shows the general anatomy of the rectum and anus. There are two well-developed anal papillæ, and between them there is a large anal pocket.

PLATE II.

Fig. 3 is a longisection of an anal papilla from an adult male mulatto. It shows,—

1. General structure and arrangement of the nerve elements, blood-vessels, etc., in anal papillæ.

2. A dermal papilla.

3. The three layers of the epidermis.

4. Ganglion-cells.

5. The arborescent branching of nerve fibers in passing to their destination in the epidermis. Compare with Fig. 5, Pl. III.

Fig. 4 is a sagittal section through a human anus. The patient suffered from external hemorrhoids. Note the dilated blood-vessels. It shows,—

1. The ental sphincter transected.

2. The thick epithelium of the pecten.

3. The change in character of the epithelium at the linea dentata from thick stratified upon the pecten to thin and simple within the rectum. Rectal mucosa (Fig. 4) should read, rectal epithelium.

4. The caudal extension of a sacculus of Horner behind the pecten. The depth varies. In some cases there is no recess behind the pecten.

5. Indentations of the ental zone of the pectineal epithelium which represent dermal papillæ.

PLATE III.

Fig. 5.—Section of a papilla to show the terminal arborization and ultimate distribution of the nerve fibers. (Compare *arborization*, Fig. 3, Pl. II.) The section was outlined with a camera lucida and studied with a Zeiss two-millimeter apochromatic oil immersion objective. The details were added free hand. It shows two kinds of fibers,—

(a) Those which break up fan-like into many fine fibers.

(b) Those which run just entad of the epidermis (interdermal fibres) to join cells of the epidermal plexus.

(c) The epidermal nerve-cells and their dendrites.

(d) A tactile cell.

(e) The ultimate branching of dendrites. Some appear to end in small bulb-like enlargements.

Fig. 6.—Four ganglion-cells from a papilla macerated in Haller's fluid, teased with needles, stained with fuchsin, and mounted in glycerin. Drawn free hand, very highly magnified.

Fig. 7.—An amyelinic nerve-trunk from the same preparation as Fig. 6. Outlined with the camera lucida, details added free hand. The trunk is seen to contain six fibrils.

Fig. 8.—Epidermal nerve-cells and their dendrites as seen in a preparation, stained according to Golgi's gold method.

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